ESSAYS

ON THE

CONSTRUCTION AND GRADUATION

OF

THERMOMETERS,

AND ON THE

HEATING AND COOLING

OF

BODIES.

BY GEORGE MARTINE, M. D.

A NEW EDITION,
WITH NOTES AND CONSIDERABLE ADDITIONS,

ESPECIALLY THE

TABLES of the Different SCALES OF HEAT,
exhibited by DR. BLACK, in his Annual
Courſe of Chemiſtry.

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ADVERTISEMENT.

As this book is recommended by Dr Black, to the Students attending his claſs, the Editor has endeavoured to render this edition more uſeful to them by inſerting ſome notes, and by adding, in the appendix, ſome tables of the ſcales of heat, which the Doctor uſually exhibits and explains in his courſe.

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ESSAY

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OF

THERMOMETERS.

A

Qui vel caloris vires, & calorem ipſum veluti in gradus partiri, vel materiæ cui inditus eſt copiam quantitatemque diſtincte percipere, &c.——Utinam id alii & perſpicaciori præditi ingenio, & quibus in ſumma tranquillitate rerum naturam perſcrutari licuerit aſſequantur; ut homines non omnium modo ſcientes, ſed omnium fere potentes fiant.

BERNARDINUS TELESIUS.

St. Andrews, Aug. 1738.

SOME OBSERVATIONS AND REFLECTIONS CONCERNING THE *CONSTRUCTION AND GRADUATION* OF THERMOMETERS.

WE cannot enough commend and admire that excellent invention of *Thermometers*, whereby we are enabled to make some judgement of the various degrees of heat in bodies. It is not our business at present to determine to whom we owe that noble and useful discovery; whether to Sanctorio, to Galileo, to Father Paul, or to Drebbel: for I find it ascribed to

all theſe by their reſpective favourers and admirers*. At firſt, as is the fate of all other inventions, Thermometers were but rude and imperfect machines, and not eaſily to be applied to ſo many purpoſes as came afterwards to be in uſe. They were very clumſy; and, as the various degrees of heat were pointed by the different contraction or expanſion of air, they came afterwards to be found uncertain, and ſometimes deceiving meaſures of heat; as

* The invention is given to Drebbel by his countrymen Boerhaave (Chem. I. 152, 156.) and Muſſchenbroek (Tent. Exp. Acad. Cim. Add. p. 8. Eſſ. de Phyſ. § 946). Fulgenzio (Life of Father Paul, p. m. 158.) aſcribes it to his maſter Father Paul Sarpi, that great oracle of the republic of Venice. But there was an humour prevailed, in thoſe days of fathering almoſt all the curious diſcoveries of the age on that great ſtateſman and virtuoſo. Vincenzio Viviani (Vit. Galil. p. 67. See too Oper. di Galil. Pref. p. 47) ſpeaks of Galileo as the inventor of Thermometers. But we know how much and how fondly he adored the memory of his great maſter. (See Hiſt. Acad. des Scien. 1703, p. 169, 175, 176, 180). Still all theſe are poſthumous claims, and they too imputed by others. But Sanctorio himſelf (Com. in Galen. Art. Med. p. 736, 842. Com. in Avicen. Can. Fen. I. p. 22, 78, 219.) expreſsly aſſumes the invention in queſtion. And Borelli (de Mot. Animal. II. Prop. 175.) and Malpighi (Oper. Poſth. p. 30) aſcribe it to him without reſerve. And theſe Florentine academicians are not to be ſuſpected of partiality in favour of one of the Patavinian ſchool.

as the bulk of air was affected not only by the difference of the heat, but likewise by the difference of the weight of the atmosphere *.

2. † Ferdinand II. great duke of Tuscany, or the gentlemen of the *Academia de l' Cimento* under his protection, made a very great improvement on those curious and useful machines. They made them with spirits inclosed in glass tubes, and these hermetically sealed. So that they could suffer nothing by the evaporation of liquor, or the various gravity of the incumbent atmosphere. And it was Thermometers made in this way which were first introduced into England by Mr. Boyle ‡, and came immediately to be of universal use among the virtuosi in all the several countries, wherever polite learning and philosophy were cultivated.

3. But there was not so much use made of those instruments as they were capable of. We have plenty of observations made with particular Thermometers at different times and places. But then these were not constructed by any fixed scale or standard. Even the Florentine Weather-glasses themselves, whose highest term was adjusted to the great sun-shine heats of that country, were too vague and indetermined: and in other places every workman made them according to his own way and fancy, without adjusting his numbers to any

* Boyle Exp. on Cold, Abr. I. p. 577, &c.

† Vivian. Vit. Galil. p. 67.

‡ Exp. on Cold, Abr. I. p. 582.

known or determined degrees of heat. And ſo they could not be compared one with another; nor could the obſervations made by different perſons, and in different parts of the world, be collated with any degree of certainty or juſtneſs. By which means, notwithſtanding all the very numerous regiſters of the weather that have been kept and publiſhed by different authors, we are ſtill at a loſs to determine the comparative differences of heat and cold in different countries and climates, and the reſult of many other obſervations.

4. Had all the Weather-glaſſes in the world been made according to one determined ſcale, theſe inconveniencies and uncertainties would have been prevented; which are now unavoidable, and muſt ſtill continue ſo, until every body agree to graduate their Thermometers in the ſame way, or at leaſt determine ſome fixed or unalterable points of heat, to which all the different ſcales of thoſe inſtruments may be reduced.

5. The great and truly honourable Mr. Boyle * found himſelf very much at a loſs for a ſtandard, whereby to meaſure heat and cold: the common inſtruments ſhewing him no more than the relative coldneſs or heat of things, but leaving him in the dark as to their poſitive degrees. Whence he could not communicate the idea of any ſuch degree to another

* Exp. on Cold, Abr. I. p. 579.

another perſon. Thermometers were then ſuch indefinite and variable things, that it ſeemed morally impoſſible from them to ſettle ſuch a meaſure of heat and cold, as we have of time, diſtance, weight, &c. there having been then no method thought upon to compare together any two different Thermometers; or the obſervations made by them. Now as bodies are variouſly affected by various heats, regularly undergoing ſuch and ſuch changes, at ſuch and ſuch degrees of it, ſo the faireſt way to fix a ſtandard method of adjuſting Thermometers would ſeem to be from ſome remarkable change a body underwent by the application of a certain degree of heat to it. In conſequence of which, Mr. Boyle propoſed the freezing of the eſſential oil of aniſeeds as a term of heat and cold that might be of uſe in making and judging of Thermometers; and ſo to graduate them from this point according to the proportional dilatations or contractions of the included ſpirits. He mentioned, too, the coldneſs requiſite to begin the congelation of diſtilled water as another fixed term that might be propoſed; for he was perſuaded that among the ordinary waters ſome were apt to freeze more eaſily than others. But the objections which he apprehended might be made to this method ſcared him ſo much, that he proſecuted no farther this conſideration of fixing a ſtandard for making and graduating Thermometers all in the ſame way:—which it is pity one of his genius and induſtry, and aſſiſted with ſuch opportunities, did not carry father; as it is

of

of ſuch importance on a thouſand occaſions in the hiſtory and philoſophy of Nature.

6. The ingenious and acute Dr. Halley * was likewiſe very ſenſible of the bad effects of that indefinite way of conſtructing Thermometers; and wiſhed to have them adjuſted to ſome determined points. He, with Mr. Boyle, lays aſide the freezing of liquors, as being, in his opinion, points of heat not ſo juſtly determinable but with a conſiderable latitude. And what he ſhews the greateſt fondneſs for, is the degree of *temperature*; ſuch as in places deep under ground, where the heat in the ſummer, or cold in winter have been found to have no manner of influence. Thus in a cave cut ſtrait into the bottom of a cliſt fronting the ſea to the depth of 130 feet, with 80 feet of earth above it, Mr. Boyle † found the ſpirit in the Thermometer to be raiſed to the ſame height both in ſummer and winter. And Meſſrs. Mariotte, De la Hire, and Maraldi aſſure us, that in the cave under the royal obſervatory at Paris, the heat continues always the ſame, ſcarcely altered by the moſt ſultry ſummer heats, or bittereſt colds of that country.

But, with Dr. Halley's leave, this degree of *temperature* I do not think a very convenient term for an univerſal conſtruction of Thermometers. Every body cannot go to Mr. Boyle's grotto: and it is but

* Phil. Tranſ. Abr. II. p. 36.

† Mem. Hiſt. of the Air, Abr. III. p. 54.

but few who can have an opportunity of making obſervations, and adjuſting Thermometers in the cave of the Pariſian obſervatory. And we are not ſure that other deep pits would coincide preciſely with the temperature of theſe places. The difference of ſoils and different depths might occaſion a conſiderable variation.

7. Another term of heat Dr. Halley * thought might be of uſe in a general graduation of Thermometers, is that of *boiling ſpirit of wine*. "Only "it muſt be obſerved, that the ſpirit of wine uſed "to this purpoſe, be highly rectified; for otherwiſe "the differing goodneſs of the ſpirit will occaſion "it to boil ſooner or later, and thereby pervert the "deſigned exactneſs." He objects, too, its great aptneſs to evaporate, and that in length of time it becomes, as it were, effete, and loſes gradually a part of its expanſive power. But truly this laſt mentioned difficulty, though repeated after Dr. Halley by ſeveral others, and commonly pretty much inſiſted on, would ſeem to be of no great weight. Well rectified ſpirit of wine, if ſealed up in a glaſs, is pretty unalterable. It cannot evaporate: and by many years experience its force of expanſion has continued the ſame; as, beſide other obſervations, we know eſpecially from the annual regiſters of Mr. De la Hire's ſpirit Thermometer, that

* Phil. Tranſ. Abr. II. p. 35.

that has been kept in the obſervatory above theſe threeſcore years by-paſt.

8. But a much more convenient term of heat, though leſs inſiſted on by Dr. Halley, is that of *boiling water*. This he found * to be a very fixed and ſettled degree of heat; and which, when once water has acquired it, cannot be increaſed by any longer continuance or length of time. And this point of heat Sir Iſaac Newton and Mr. Amontons were juſtly very fond of in ſettling the limits of their reſpective Thermometers: wherein too they have been imitated by all thoſe that came after them.

9. Though I could ſcarcely find any ſenſible difference in various waters, differing conſiderably in weight, ſaltneſs, cleanneſs, &c. ſo as that Mr. Taglini's objections † againſt the fixedneſs of this point are of no force; yet truly this heat of *boiling water* is not at all times and places ſo abſolutely fixed and invariable, as moſt people are ready to conclude from Dr. Halley's and Mr. Amontons's obſervations. The fixedneſs or volatility of water depends very much not only on the coheſion of its particles, but alſo on the preſſure of the incumbent atmoſphere:

* Phil. Tranſ. Abr. II. p. 34. See, too, Amontons in Mem. Acad. Sc. 1699, p. 156. 1702, p. 210.

† See Mem. Acad. Sc. 1730, p. 714.

atmoſphere: * for, in a veſſel much exhauſted of air, water and other liquors, being freed of moſt of the ordinary preſſure they undergo, boil in a very moderate degree of warmth, much below what in the open air is uſually requiſite to ſet them a boiling. And, agreeable hereto, Fahrenheit actually found †, that water was capable of a greater or leſs degree of heat in boiling, according to the greater or leſs weight of the atmoſphere, or the greater or leſs height of the mercury in the barometer. But in ordinary changes of the weather, the difference is not very great ‡. And farther, we may avoid all errors that might ariſe from any thing of that ſort, if we make our obſervations on the heat of boiling water, and adjuſt this term of heat at a middle ſtate

* See Boyle Phyſico. Mech. Exp. Abr. II. p. 473, 474. Newton. Opt. p. 318.

† Phil. Tranſ. Abr. VI. 2. p. 18. Boerh. Chem. I. p. 171.

‡ It is not ſo great as Dr. Boerhaave, (Chem. I. p. 171.) in giving an account of Fahrenheit's obſervations, reckoned. In an alteration of 3 inches in the height of the mercury in the barometer, he ſays, the boiling heat is found to differ 8 or 9 degrees. I did not find it ſo very much by the different weights of the atmoſphere. From the experiments I have made I judge that, by the riſe or fall of the quickſilver an inch in the barometer, the boiling heat of water varieth ſomewhat leſs than 2 degrees.

ſtate of the atmoſphere in places near the level of the ſea, when the mercury in the barometer ſtands at about 30 inches, or a very little under it. And the ſame caution will be neceſſary in judging of the heat of *boiling ſpirit of wine*, or of the *boiling heat* of any other liquor.

10. It was on this principle chiefly of the determined fixedneſs of the heat of *boiling water*, that Mr. Amontons * contrived his univerſal Thermometer. It was indeed a pretty contrivance: but it never was, nor never could be, of univerſal uſe; nor could it anſwer the deſign of its ingenious author. Its conſtruction is too difficult and complex; the machine itſelf is too bulky and incumbered to be eaſily managed, or carried from place to place. And then it is ſuppoſed to be fitted at a due temperature of the air, as in the ſpring and autumn at Paris: which, beſide that it is in itſelf ſomething too indefinite, at other times and places we cannot well be ſure of. And the air of that temperature he reckoned to be dilated juſt one third by the heat of boiling water. But the dilatation of the air is not ſo regularly proportional to its heat; nor is its dilatation by a given heat near ſo uniform as he all along ſuppoſed. This depends much on its moiſture: † for dry air does not expand near ſo much

* Mem. Acad. Sc. 1702, p, 204, &c.

† See Hiſt. Acad. Sc. 1708, p. 15. Mem. p. 370. Muſſchenbr. Tent. Exp. Acad. Cim. Add. p. 40. Eſſ. de Phyſ. § 1402.

much by a given heat, as air ſtored with watry particles; which, by being turned into ſteam, increaſe vaſtly the ſeeming volume of the air. So then as Mr. Amonton's Thermometer is affected by all theſe and other inconveniences*, it is no wonder it was imitated by very few, and never came to be of general uſe in the world.

11. From this one determined point of the heat of *boiling water* there may, however, be laid down a general method of conſtructing Thermometers all in the ſame way, ſo as that they ſhall correſpond with one another in all the various degrees of heat. It is, as Mr. Boyle † propoſed long ago, by marking the degree of expanſion or contraction of the fluid of the Thermometers, as the heat applied is either greater or leſs than that of *boiling water*. Suppoſing, for example, the whole volume of this fluid to conſiſt of 10,000 parts, it is to mark on the tube, where that volume is expanded by heat, or contracted by cold, 1, 2, 3, 4, &c. of theſe parts. All which may be done at any time by different perſons and in different places, ſo as that they ſhall anſwer preciſely to one another.

12. This is a very plauſible method, and has been actually tried by ſome, as we ſhall afterwards have

* See Mr. de Reamur in Mem. Acad. Sc. 1730. p. 654.

† Exp. on Cold, Abr. I. p. 579.

occaſion to ſee: and yet in practice it will not be found very eaſy to determine exactly all the diviſions from the alteration of the bulk of the fluid; beſide other unavoidable inconveniences and uncertainties we ſhall by and by have occaſion to take notice of. It is ſufficient, and will be much eaſier and more convenient, in ſettling an univerſal method of conſtructing Thermometers, to determine at leaſt two fixed points of heat at a conſiderable diſtance the one from the other, and to divide on the tube or ſcale the intermediate ſpace into any convenient number of equal parts or degrees. *Boiling water*, in the circumſtances we propoſed, we juſt now found to be a pretty uniform and fixed degree of heat. And *water* juſt *freezing*, if that come out always the ſame, will anſwer the purpoſe moſt readily of any degree we could think of.

13. It is true, Dr Halley * thought this to be a point admitting a conſiderable latitude. And ſome have ſuſpected that water freezes at different degrees of heat in different ſeaſons, countries and climates. And Dr Cyrilli's obſervations † would ſeem to confirm it. At Naples he found water to freeze when his Thermometer was 10 degrees above the freezing point, as it had been conſtructed in England

* Phil. Tranſ. Abr. II. p. 36.

† Phil. Tranſ. No. 424, p. 336. No. 430, p. 189. No. 434, p. 407, 408. No. 435, p. 464.

England by the directions of the Royal Society; and Father Martini * talks of the frosts in the province of Pekin in China as greater than its latitude of 42 degrees would induce one to expect, the rivers being often frozen for two months together, *&c.* And adds, that it is surprising the Europeans should remain unaffected by this cold, and slight it as unable to produce ice in their quarter of the world. From all which one might be ready to conclude, with Dr Derham †, Prof. Musschenbroek ‡, and others, that the farther north we go, it takes the greater degree of cold to freeze water. And what might strengthen such a suspicion is, that I found some of the Dutch mercurial Thermometers made at Amsterdam, in which the *freezing point* was marked at *gr.* 32, to be a degree or two lower here when immersed in thawing snow or beaten ice beginning to melt.

14. But I am convinced all this seeming difference flows from the carelessness of observers, or errors of the workmen. Or what if Dr Cyrilli kept his weather-glass shut up and sheltered in a house while it freezed abroad? As I know it is but too ordinary with those who pretend to keep registers of the weather. To satisfy myself in this article, I took a very

* Atlas Sinens. p. 27. See too, Boyle's Exp. on Cold, Abr. I. p. 577. Reaumur in Mem. Ac. Sc. 1734, p. 233.

† Phil. Trans. ibid. ‡ Eff. de Phys. § 913.

fair method of inquiring if there was really any ſuch difference in the cold of *freezing water* in different climates. I marked two mercurial Thermometers here in the latitude of 56 deg. 20 min. and got a correſpondent of mine to mark ſome others at London in the latitude of 51 deg. 32 min. all at the freezing point in ſnow or powdered ice melting: and, upon exchanging theſe Thermometers, we found them, when again immerged in thawing ſnow on ice, ſtill to point at the very ſame marks preciſely, without the leaſt obſervable difference. Were there any odds occaſioned by the difference of climates, would not near 5 degrees of latitude have ſhewn it very ſenſibly *? And at this ſame very mark does the quickſilver ſtand in ſuch thawing ice or ſnow at all ſeaſons of the year, in ſummer or winter, in cold weather or warm weather, under a light or a heavy atmoſphere, *&c.* From whence I conclude the *freezing point* to be a very conſtant and ſettled degree of heat, more fixed and determined than even that of *boiling water*, and conſequently

* The univerſality and fixedneſs of the term of congelation I can now affirm with ſtill greater confidence and certainty after the trials I lately made, not only at London, but at Paris in the latitude of 48 deg. 50 min. and Dijon in the latitude 47 deg. 20 min. by which I found that preciſely the ſame degree of cold was requiſite to freeze water in Burgundy and in the iſle of France, as in our northern climates.

conſequently very fit to be one of the fixed limits in adjuſting our Thermometers.

15. The fixedneſs then of the freezing point, I think we may take for granted, and ſufficiently eſtabliſhed by theſe obſervations, notwithſtanding what Profeſſor Taglini may have ſaid to the contrary; and the unneceſſary conceſſions Mr. De Reaumur thought fit to make on that head *; and the obſervations adduced by Dr. Muſſchenbroek †, by which he would prove the *freezing of water* to begin in various degrees of cold, depending on ſome ſaline additional mixture from the air. All which may be allowed to ſhew, that in ſome places and circumſtances water freezes more or leſs eaſily, though the degree of cold in this act of *natural freezing* be, for any thing we can perceive, in all pretty nearly the ſame.

16. The cold of *water beginning to freeze*, or which is the ſame thing of *ice beginning to melt*, is ſuch a convenient fixed point, ſuch a remarkable period of heat and cold, and withal ſo eaſily determined by emerging the bulb of the Thermometer in thawing ſnow or ice, that it is ſurpriſing ſo few have taken it into the ſcale of their Thermometers, that theirs might be the better compared

 with

* Mem. Acad. Sc. 1730, p. 712.

† Tent. Acad. Cim. Add. p. 184, 185. Eſſ. de Phyſ. § 913, *&c.*

with other peoples obſervations. We are not abſolutely ſure even of this part of the ſcale of the Florentine weather-glaſſes. And the French have not yet preciſely determined the *freezing point* in Mr. De la Hire's ſtandard Thermometer of the Obſervatory, by which the regiſter of the weather has been ſo very long kept, and with which they ſometimes compare other obſervations: and moſt of the other obſervations of the weather, both in the Memoirs of the Academy of Sciences and in the Tranſactions of the Royal Society, are done with Thermometers ſo negligently conſtructed, that we are left altogether uncertain of their degrees of heat: moſt of thoſe that have the *freezing point* marked on them having it very erroneouſly graduated, and alſo having no other determined or known period of heat; and ſo coming to be as indefinite and uncertain as the other.

17. The great Sir Iſaac Newton thought the ſettling the degrees of heat and cold well worth his notice; and, as he carried every thing he meddled with beyond what any body had done before him, and generally with a greater than ordinary exactneſs and preciſion, ſo he * laid down a method of adjuſting Thermometers in a more definite way than had been done hitherto. We have already † found it

* Phil. Tranſ. Abr. IV. 2. p. 1, &c.

† § 12.

it neceſſary, at leaſt convenient, to fix on two determined periods of heat to make up an intelligible ſcale of its various degrees. We have likewiſe * found *water freezing* and *water boiling* to be in two points of heat very convenient to ſuch a purpoſe. And theſe are the very degrees of heat he pitched upon. The liquor he uſed was Lintſeed Oil, a homogeneous fluid enough, and capable of a conſiderable rarefaction, and not having been obſerved to freeze even in very great colds, and able to bear a great heat without boiling. Suppoſing the bulb when immerged in *thawing ſnow* to contain 10,000 parts, he found the oil expanded by the heat of the *human body* ſo as to to take up $\frac{1}{39}$ more ſpace, or 10,256 ſuch parts: and by the heat of *water boiling* ſtrongly 10,725; and by the heat of *melting tin* 11, 516, beyond which he did not carry his oil Thermometer. So that, reckoning the *freezing point* as a common limit between heat and cold, he began his ſcale there, marking it *gr.* 0; and the heat of the *human body* he made *gr.* 12; and conſequently the heat of *boiling water* was expreſſed by *gr.* $34 = \frac{725 \times 12}{256}$; and *melting tin* by *gr.* 71.

28. I wiſh the world would have received this or any other determined ſcale for adjuſting their Thermometers. But I ſuppoſe they might be apprehenſive

* § 8, 14.

ſive of ſome inconveniences in this ſcheme. Beſides ſome inconſiderable arithmetical errors in Sir Iſaac's paper, and ſome few not accurately enough made obſervations of no great moment, they would allege * that he had expreſſed himſelf as if he had thought the point of *freezing water* to be the loweſt degree of heat. And indeed he has not mentioned any winter cold beyond that: though, as we ſhall take notice on another occaſion, we ſometimes experience vaſtly intenſer colds: in conſequence of which, it would be eaſy to protract Sir Iſaac's ſcale downward below *gr.* 0, or the freezing point, and ſo to make it as ſerviceable in common uſe, even for great degrees of cold, as other Thermometers.

But there is another difficulty which will hold in all oil Thermometers, or any made with a viſcid liquor, that it adheres too much to the ſides of the tube. In a ſudden cold or fall of the oil, a good deal ſticks by the way, and only ſinks gradually after, ſo that at firſt the ſurface appears really lower than the preſent temperature requires. And beſide, as at all times ſome muſt continue to ſtick and moiſten the inſide of the tube, in different degrees of heat and cold, the oil becoming alternately more or leſs viſcid, will adhere ſometimes more and ſometimes leſs; and therefore will inevitably diſturb the regulatity and uniformity of the Thermometer.

19. The

* See Amontons in Mem. Acad. Sc. 1703, p. 233.

19. The Florentin Thermometers made with ſpirit of wine were by no means ſo liable to errors of this kind. The ſpirit indeed muſt moiſten the inſide of the tube: but as this is ſo very thin a liquor, it is probable that moiſtening is always pretty uniform, and extremely thin: ſo as that it can have no other effect but to render the tube a very little narrower. And ſo truly rectified ſpirit of wine has been more uſed in Thermometers than any other liquor. It is very tickliſh, is eaſily and very much affected by heat and cold; nor does it ſoon gather air bubbles, as watry fluids are ready to do even in no very great heats. But, as we ſaid before*, theſe ſpirit Thermometers did not uſe to be reduced to a fixed ſtandard. At length Mr. De Reaumur † has in a very ingenious way attempted to eſtabliſh a general conſtruction of ſuch Thermometers, which might be copied at all times, and in all countries: and ſo to ſettle, as it were, a general correſpondence of obſervations that ſhould be made by ſuch inſtruments. He adjuſted his Thermometer to the *freezing point* by an artificial mixture: and then, immerging it in *boiling water*, found how much it was dilated by that heat, in the way Sir Iſaac Newton had managed his oil Thermometers. The quantity of ſpirits in his glaſs he ſuppoſed to be 1000 parts; and he found to how many of theſe parts

* § 3, 4, 19.

† Mem. Acad. Sc. 1730, p. 645, &c.

parts the bulk of the liquor was dilated by that boiling heat. The ſtronger the ſpirits, this dilatation is found always the greater. The beſt ſpirit of wine commonly ſold, from this *artificial freezing of water*, to that *boiling heat*, was dilated 87½ of thoſe parts*: and a mixture of ſuch a ſtrong ſpirit and water in equal portions (which would be about the ſtate of common brandy) was expanded only 62½ ſuch parts †. He ſpeaks too of a ſpirit ſo ſtrong as to have the dilatation of 90 in its *boiling heat* ‡. But what he judged moſt convenient for his ordinary Thermometers was a ſpirit of ſuch a degree of ſtrength, as in the above period of heat, to be dilated juſt 80 of theſe 1000 parts**.

20. This imitation of Sir Iſaac Newton with ſpirit of wine inſtead of oil is a promiſing enough method of making a ſettled ſtandard ſcale for Thermometers; and accordingly one of them conſtructed by Mr De Reaumur himſelf is now placed in the Royal Obſervatory at Paris; and a journal kept of the weather by it. And others conſtructed in the ſame way have been ſent to different quarters of the world, to compare the degrees of heat and different climates: a project long ago of the great Colbert's ⸸, but never till now ſatisfactorily executed.

* Mem. Acad. Sc. 1730. p. 690. † Ibid. p. 692.
‡ Ibid. 1734, p. 161.
** Ibid. 1730. p. 697, 698. and fig. 8.
⸸ See Mem. Acad. Sc. 1702. p. 209.

executed. Obſervations have been made with them in the Torrid Zone. And the French Academicians had them in their philoſophical embaſſy to the north, for determining the figure of the earth. And yet I am afraid theſe Thermometers are conſtructed on principles, that will by no means be found ſo accurate as were to be wiſhed and expected in ſuch a caſe: Mr De Reaumur determines his freezing point, not from *thawing ſnow* or *ice*, * but from an *artificial congelation of water* in warm weather. And as he † uſes very large bulbs for his glaſſes, it may be 3 or 4 inches in diameter, I am apt to think that, before the due temperature of the ſurrounding ice can be thoroughly propagated to the whole contained ſpirits, it will be quite melted down again; and ſo the *freezing point* marked much higher than what it ſhould be ‡: He indeed †† ſpeaks of a quarter of an hour as ſufficient to bring the contained ſpirit to the temperature of the ambient *medium*. But as far as as I can judge from my obſervations (and many I have made on

* Mem. Acad. Sc. 1730, p. 655, 656, 680, 681, 712.

† Ibid. p. 660, 710.

‡ From collating ſome obſervations together, I reckon Mr De Reaumur's mark of freezing water, inſtead of coinciding with Farenheit's *gr.* 32, as it ſhould do, to correſpond with *gr.* 34. or a little above it.

†† Ibid. p. 711.

on this ſubject), it would rather take ſome hours to penetrate thoroughly ſuch a great bulk of any liquor, and reduce it fully to its own degree of heat. And ſo Thermometers of great bulbs can never be uſed with ſucceſs, or truſted to in common experiments of the heat of bodies, or obſervations of the weather: as we may be ſatisfied by collating the ſeveral obſervations in the Royal Obſervatory made with De la Hire's and De Reaumur's Thermometers, which at different times I find to quadrate very ill together, juſt I ſuppoſe from that cauſe of the different ſizes of their bulbs*. For large bulbs can never be ſo quickly influenced by great and ſudden variations of heat and cold, as to make theſe changes, if they laſt but a ſhort while, ſufficiently remarkable, or to ſhew their real and full quantities. Small bulbs and ſmall tubes are (notwithſtanding the imaginary faults and difficulties ſtarted againſt them by Mr De Reaumur †) vaſtly more convenient, and may be conſtructed ſufficiently accurate. I have them made with capillary bores that correſpond almoſt entirely to one another in all degrees of heat; and conſequently muſt be allowed to have all the exactneſs that can be imagined or deſired in ſuch inſtruments.

21. But

* The diameter of the bulb of Mr De Reaumur's I found to be about $3\frac{1}{2}$ inches; while the other was leſs than 2 inches.

† Mem. Acad. Sc. 1730. p. 650, 656, 659.

21. But if we cannot truſt to Mr De Reaumur's *point of congelation*, what ſhall we ſay to his other fixed term, to wit, the heat of *boiling water?* This, I humbly think, is, under his management, ſtill more vague and uncertain. As water, were it ſurrounded by melted tin, though it would boil and foam and ſuffer very great agitation, is yet incapable of being warmed beyond its ordinary great boiling heat, and continues always much colder than melted tin; juſt ſo, as I experienced upon trial, ſpirit of wine, though immerged in boiling water, can never acquire near ſuch a great heat, but keeps always a good deal under it, though bubbling and foaming, and toſſed to a very great degree. The ſpirit then in the Thermometer is abſolutely incapable of ſuch a great heat as Mr De Reaumur aſcribed to it; and that not by a ſmall or trifling difference. I find highly rectified ſpirit of wine cannot be heated beyond *gr.* 175, or ſo, in Farenheit's Thermometer, while boiling water raiſeth the quickſilver 37 degrees higher: and common brandy was able to conceive a heat no greater than about *gr.* 190. So far was Mr De Reaumur in the wrong when he thought that all ſpirits, weak and ſtrong, immerged in *boiling water* received a given degree of heat, and that equal to the heat of the ſurrounding water. I ſuppoſe his ſtandard ſpirit could take on a heat of about *gr.* 180; leſs by 32 degrees than what he reckoned.

22. Beſide all this, I truly think ſpirit of wine, though good enough for ordinary weather-glaſſes in temperate climates, is yet not ſo fit a fluid whereof to make ſtandard Thermometers. It is incapable of bearing very great heats, or very great colds. It boils ſooner than any other liquor. And though it keeps fluid in pretty ſtrong colds, yet it would ſeem, from ſome experiments, that it does not condenſe very regularly in them: and at Torneao near the polar circle, the winter cold was ſo violent, that the ſpirits were frozen in all their Thermometers *. So that the latitude of heat ſpirit of wine is capable of expreſſing, is by much too limited to be of very great or univerſal uſe.

23. What fluid then ſhall we take for our Thermometers? We have found inconveniences in air, oil, and ſpirits; and water is more exceptionable than any of them. We have, it ſeems, nothing left but quickſilver. This is a very moveable and tickliſh fluid; it both heats and cools faſter than any liquor we know, or have had occaſion to try; faſter I am ſure than water, oil, or even ſpirit of wine; it never freezes by any degree of cold hitherto obſerved, and bears a great deal of heat before it arrives at a boiling expanſion, and, if well purified, does not wet or ſtick to the inſide of the

* See de Maupert. Fig. de la Terre, p. 58.

the tube. Dr Halley *, though appriſed but of ſome of theſe remarkable properties, thought it a fluid very fit for Thermometers, were but its expanſion more conſiderable. However, as any inconvenience ariſing from this conſideration may be avoided by making the bulb have a great proportion to the tube, ſo it is now very deſervedly come to be in the greateſt uſe in the Thermometers that people would moſt truſt to. It is ſaid †, that they were firſt contrived by that curious mathematician Olaus Roemer. Mr Fahrenheit in Amſterdam, and other workmen in that country, manufactured very many of them, and that in a portable and mighty convenient form for many purpoſes, making them very ſmall, and incloſing the tube in another glaſs hermetically ſealed. From Holland they were diſtributed into different quarters of the world, and have been imitated in ſome other places. And now they are made no where in greater perfection, or with greater exactneſs, than by our countryman Wilſon at London.

24. As Roemer's or Fahrenheit's ſcale is convenient enough, I wiſh it were univerſally kept and uſed, to preſerve an uniformity in our obſervations; and ſo that every body, when they ſpeak of experiments wherein the heat of bodies was adjuſted,

* Phil. Tranſ. Abr. II. p. 34.

† See Boerh. Chem I. p 710.

or pretended to be obſerved by Thermometers, were to have the ſame language; and ſo be univerſally underſtood.

In this Thermometer the bulb is ſuppoſed to contain, as Dr Boerhaave * and Dr Muſſchenbroek † tell us, 11124 parts of quickſilver, which ſtands at the loweſt mark, or *gr.* 0, in a very intenſe intolerable cold, being ſurrounded with a mixture of ſnow or beaten ice and ſal ammoniac or ſea-ſalt ‡.

If the ſame bulb be immerged in *ſnow* or *ice thawing* naturally, or in *water beginning to freeze*, the quickſilver is dilated, and ſo riſes in the tube 32 of theſe 11124 parts; and therefore the ſpace of the tube from *gr.* 0 to the *freezing point gr.* 32, is divided into theſe 32 equal parts ‖.

When the Thermometer is placed in water brought to ſtrong *boiling*, (the atmoſphere being in the condition formerly mentioned **,) the quickſilver is dilated 212 of theſe parts beyond its original bulk of 11124, ſo as now to poſſeſs in the bulb and tube together a ſpace equal to 11336 ſuch parts: and the ſpace from *gr.* 32 to *gr* 212, is divided into 180 equal parts or degrees of the Thermometer ††; which, if the tube be long enough, may

* Chem. I. p. 174. † Eſſ. de Phyſ. § 948.

‡ Fahrenh. in Phil. Tranſ. Abr. VI. 2. p. 52. Muſſchenbr. Diſſ. Phyſ. p 680. Eſſ. de Phyſ. § 948.

‖ Fahrenh. in Phil. Tranſ. Abr. VI. 2. p 52.

** § 9.

†† Fahrenh. in Phil. Tranſ. Abr. VI. 2. p. 18. 52.

may be protracted as far as is convenient. It may go well enough to *gr.* 600, and not much farther; for, with a heat but little greater than that, the mercury begins to boil.

25. Dr Boerhaave is not always quite conſiſtent with himſelf in his account of the number of parts into which the mercury in the bulb is ſuppoſed to be divided. In another place *, inſtead of 11124, he reckons only 10782, and afterwards † he raiſes it to 11520, (which I take to be nearer the truth), and yet ſtill ſpeaks of a given heat as expanding the quickſilver the ſame number of parts as in the other ſupputation. Which of his ſuppoſitions is right I am not abſolutely ſure of before making trial, nor need we much to care; for, without all that *apparatus*, I humbly think the eaſieſt and ſureſt way too, and what in practice I have followed, is not to be ſolicitous about the bulk of the quickſilver, but to fill the bulb and tube ſo, as that in freezing water, or melting ice, the mercury ſhall ſtand at a convenient height, which muſt be very nicely marked *gr.* 32. and then as accurately to obſerve where it ſtands when dilated by the heat of boiling water to *gr.* 212. The intermediate ſpace is then divided into 180 degrees; which ſcale may be protracted upwards and downwards as far as we ſhall judge convenient. In the conſtruction of

* Chem. L. p. 265.

† Ibid. Expl. Tab V. fig 3.

theſe Thermometers the two great limiting or fixed points being *freezing water* and *boiling water*; which we found to be the moſt convenient periods of heat for adjuſting theſe inſtruments.

26. Indeed in all this we have ſuppoſed the bore of the tube to be perfectly cylindrical; which cannot always be obtained. But though it be tapering, or ſomewhat unequal, it is eaſy to manage that matter, by making a ſmall portion of the quickſilver, as much for example, as fills up a half, or, if you pleaſe, a whole inch, ſlide backward and forward in the tube: and by this means to find the proportions of all its inequalities, and from thence to adjuſt your diviſions to a ſcale of the moſt perfect equality.

27. The conceiving the bulk of the contained mercury at the beginning of the ſcale to be either 10782, or 11124, or 11520, or, as I gueſs it ſhould be near 11790 parts, and its expanſion from thence by the heat of boiling water to be 212 of theſe parts, was, to be ſure, a diviſion originally quite arbitrary. And I confeſs there might have been a more convenient one fixed upon at firſt, and adopted, yet, if this were not now ſo univerſally known and uſed; and Thermometers conſtructed in that form every where ſcattered up and down, and in the hands of moſt of the Virtuoſi in Europe. I ſhall readily allow that Mr De l' Iſle's at Peterſburgh,

Peterſburgh, might have had a greater look of ſimplicity. * In his the whole bulk of quickſilver, when immerged in *boiling water*, is conceived to be divided into 10000, or rather 100000 parts; and from this one fixed point the various degrees of heat either above or below it are marked in theſe parts on the tube or ſcale, by the various expanſion or contraction of the quickſilver in all the imaginable variety of heat. "As pure mercury," ſays he, "is of the ſame nature every where, nor is liable "to any alteration from being incloſed in a tube; "and as it is probable that, taking it equally puri-"fied, it will in different countries be ſubject to "the ſame expanſion, if expoſed to the ſame de-"gree of heat; for this reaſon he is perſuaded "theſe Thermometers may very well ſerve to "compare the temperature of different coun-"tries." And indeed ſuch a conſtruction bids fair for being a very good ſtandard method for graduating Thermometers all in the ſame way; and is much leſs liable to uncertainties than that ſimilar one of Mr De Reaumur, whereof we have already given an account †. However, if Mr De l'Iſle had pleaſed, I cannot but think it would have been rather ſomething better to have made the integer of 100000 parts, or fixed point, at *freezing water*; and from thence to compute the dilatations or condenſations

* Phil. Tranſ. N. 441. p. 222.

† § 19, 20, 21.

denſations of the quickſilver in thoſe parts. All the common obſervations of the weather, &c. would have been expreſſed by numbers increaſing as the heat increaſed; which ſurely is the more natural way. Nor would there have been great incongruity or inconvenience in expreſſing, after the manner of Mr De Reaumur, the few obſervations we have below ſimple freezing by numbers of contraction below *gr.* 0, or 100000.

28. But, as I ſaid before *, however promiſing in theory ſuch a ſcheme may appear, it will not in practice be found very eaſy to determine exactly all the diviſions from the alteration of the bulk of the contained fluid. And beſide, as glaſs itſelf is dilated by heat, though in a leſs proportion than quickſilver, ſo that it is only the exceſs of the dilatation of the contained fluid above that of the glaſs that is obſervable; if different kinds of glaſs be differently affected by a given degree of heat, this will make a ſeeming difference in the dilatations of the quickſilver in the Thermometers conſtructed in the Newtonian method, either by Mr De Reaumur's, or Mr De l'Iſle's rules. Now Dr Boerhaave †, from Fahrenheit's obſervations, ſpeaks of different kinds of glaſs as very differently affected by heat. And upon inquiry I was informed that Dr Muſſchenbroek found by his Pyrometer, that tubes

* § 12. † Chem. I. p. 141

tubes of different kinds of glaſs were variouſly affected, ſome more, ſome leſs, by the ſame degree of heat. From whence Thermometers conſtructed of ſuch different ſorts of glaſs would neceſſarily make the ſeeming dilatation of the contained fluid appear at different degrees in the very ſame point of heat. And accordingly Mr Campbell, an ingenious and worthy member of the Royal Society, has, by experiments made with all imaginable exactneſs and ſcrupuloſity, found, in Thermometers conſtructed in Mr De l'Iſle's way, the quickſilver to ſtand at different degrees of the ſcale, when immerged in thawing ſnow. In ſome it was at *gr.* 154, in others at 156, and in another at 158: and emptying the tubes, and preparing them again, and that ſometimes with other mercury, he always, even in a great many trials, found the reſult come out the very ſame. So careful and exact had he been that the ſame tubes gave always the ſame degrees of dilatation as nearly as could be expected in ſuch nice and ſubtile experiments. One of Mr De l'Iſle's own Thermometers, which I tried very carefully, gave me always the quickſilver at about *gr.* 150. In another of his, where on the one ſide he has put Fahrenheit's ſcale, I ſee *gr.* 32. over againſt his own *gr.* 148¼. In one conſtructed by Mr De Monier at Paris, on De l'Iſle's principles, I ſaw the *terme de congelation* put down at *gr.* 148. Nay, by Mr De l'Iſle's own accounts, I find his weather-glaſſes diſagreeing conſiderably from one another.

another. So uncertain and precarious would this way of conſtructing Thermometers ſeem to be. From all which I humbly think that it is better and more convenient to drop this method altogether, and to fix on two points of heat at a conſiderable diſtance the one from the other; and to divide the intermediate ſpace of the tube into a convenient number of equal parts or degrees: as we juſt now propoſed * to be done in our imitations of Roemer's or Fahrenheit's Thermometers.

26. To enlarge our views of heat, and to enable us to compare other Thermometers with theſe, (which after this I wiſh were always to be the ſtandard), it would not be amiſs to obſerve a great many remarkable periods of heat and cold that have been taken notice of by others, and to determine where they fall on Fahrenheit's ſcale. We ſhould determine about what degrees on it the ſeveral ſorts of weather are marked: the various degrees of animal heat; what degrees of heat reduce ſuch and ſuch conſiſtent bodies into a fluid ſtate; the quantities of heat required to boil the fluids we have occaſion to try, &c. But the comparing the different Thermometers which have been in uſe in the world, and the determination of the various degrees of heat in bodies, make fruitful enough ſubjects for other curious and uſeful inquiries.

THE

* § 24, 25, 26.

THE

COMPARISON

OF

DIFFERENT THERMOMETERS.

London, 1740.

AN

ESSAY

TOWARDS COMPARING

DIFFERENT THERMOMETERS

WITH ONE ANOTHER

WE had occaſion formerly to take notice of the great uncertainty of thermometrical obſervations, by reaſon of the vague and inconſtant way that people had of making their inſtruments. However, it will be worth while narrowly to inquire, as far as our lights can carry us, into the principles on which they were conſtructed; and if we can find out theſe principles ſo as to compare the old Thermometers with any regular one we are well acquainted with, we ſhall recover, as it were, the loſt obſervations of our predeceſſors; loſt for want of knowing the meaning of their numbers and graduations. And then obſervations made at different times and places by any known inſtru-

ments will be no longer uſeleſs memorandums. We ſhall be able to compare them with one another, and with our own obſervations, and with the degrees of heat we are acquainted with.

2. As Sanctorio ſeems to be the firſt who had a notion of meaſuring the various degrees of heat by the dilatation of bodies, people will be apt to expect, and many will fondly wiſh, that he had left us his method of numbering the degrees of his Thermometers. Though, to acknowledge the truth, it would be a matter of more curioſity than uſe, as they were affected by the difference of weight of the atmoſphere, as well as by the difference of heat of the ambient medium. To remedy which inconvenience, the virtuoſi of the Cimentin Academy contrived their Thermometers in a better way; carefully ſealing up the included ſpirits from any influence of the gravity of the atmoſphere; and marking on the tubes, or on the ſcales fixed to the tubes, numbers whereby to judge of the various dilatations of thoſe ſpirits by the various degrees of the heat applied.

I am ſurpriſed to find Dr Muſſchenbroek *, who had been at the pains to give a Latin tranſlation of their whole work, and to enlarge and embelliſh it with excellent additions, repreſenting theſe Florentine Thermometers as conſtructed in a very looſe, arbitrary

* Eſſ. de Phyſ. § 947.

arbitrary and indefinite way, and without any rule at all. This is an imputation to which they are leſs liable than many others that came after them. They made them of ſeveral ſorts, ſome with greater and ſome with leſs accuracy. But in the conſtructing of thoſe in which they could moſt confide *, they tell us expreſsly at what degree the ſpirit ſtood in the ordinary cold of ſimple ice or ſnow. Which, as their experiments were done within doors in Italy, I take commonly to have been in a thawing ſtate, and conſequently to point out to us the degree of freezing water, which we found † to be a very fixed period of heat and cold, coinciding, we know ‡, with our *gr.* 32. Thus, in their 1ſt ſort, this point of heat fell at *gr.* 20 §; and in their 2d to about *gr.* 13½ ‖.

So then we have one fixed and intelligible point of heat in their Thermometers, which is more than we have in thoſe of many others. But from one point we cannot judge of the reſt of the numbers; and it muſt be confeſſed their higheſt degree of heat is not defined in a way we could have wiſhed. They tell us that in their firſt or long Thermometer the ſpirit, when expoſed to the great midſummer heats in their country, roſe to where they

* Tent. Exp. Acad. Cim p. 5.

† Eſſ I § 14.

‡ Ibid § 24.

§ Tent. Exp. Acad. Cim p 2, 7.

‖ Ibid II. p. 129.

marked *gr.* 80 *. And the ſpirit in the 2d or ſmaller Thermometer in ſuch a heat ſtood at *gr.* 40†. This indeed is a very incongruous way of graduating Thermometers, as the great heat of the ſummer ſun is ſuch an indefinite degree of heat in different days, years, climates, *&c.* And yet, by good chance, there is left us a way to judge of the particular ſummer heat they happened to pitch upon; and of finding whereabouts it would have fallen in a Thermometer conſtructed in Fahrenheit's way, which we have taken up as our ſtandard. To affirm this will, I know, be looked on at firſt ſight as pretending to a thing in itſelf loſt, and now impracticable. But Borelli and Malpighi, two curious and careful obſervers of nature, luckily had occaſion to tell us, that the *viſcera* of ſome hot animals, ſuch as of cows, deer, *&c.* raiſed the ſpirit in the ſmall Florentine Thermometer to about *gr.* 40. the very degree of this their ſummer ſun heat. And that animal heat I find to coincide with *gr.* 102, or thereabouts in ours. From which two periods of heat determined in both Thermometers, we can make a pretty good eſtimate of all obſervations made by any of the regular and well conſtructed Florentine glaſſes; as we may ſee by looking on the table at No. I, II, III.

3. The Thermometers that came to be uſed in the world, were all imitations of theſe of the *Academia*

* Tent. Exp. Acad. Cim. p. 2, 4. † Ibid. p. 4.

demie de l' Cimento, but not conſtructed in ſuch a regular way, or upon ſuch determined principles. In France Mr Hubin was employed in making them for the *Academie des Sciences* at Paris. But we find they were not madè all perfectly alike. The Indian miſſionaries * tell us, that they uſed thoſe that were graduated loweſt. However, we may reckon at a medium that which Mr Amontons gives us a view of in the Memoirs †, under the name of the *Ancienne Thermometre*. In it the freezing point was at *gr.* 25, correſponding conſequently to Fahrenheit's *gr.* 32. and the heat of the cave of the Obſervatory was *gr.* 50, which I know to be our *gr.* 53. So that the compariſon is eaſy in the table at No. I. IV.

4. But I know not many obſervations made with this Weather-glaſs. It is much more to our purpoſe to know the conſtructon of that very remarkable one of Mr De la Hire, that has ſtood in the Royal Obſervatory at Paris above theſe threeſcore years, and by which a regiſter of the weather has been conſtantly kept. And yet we cannot but regret that neither Mr De la Hire himſelf, nor any of thoſe that ſucceeded him in that office, have been at the pains exactly to determine any two

 points

* Mem Acad. Sc. 1666.——1698. VII. p. 835.

† Mem. Acad. Sc. 1703. p 53.

points of it, ſo as that we may be enabled to imitate it; or compare it with other Thermometers; though I hope we ſhall be able to trace it pretty near the truth. We are expreſsly told, that the ſpirit in it always ſtands at *gr.* 48. in the cave of the Obſervatory *, correſponding by this to *gr.* 53. in Fahrenheit's. And when it freezes in the fields, they ſpeak of their Thermometers ſtanding in the open tower as pointing at from *gr.* 30. to *gr.* 32 †: ſomething below which the real degree of freezing would be. And from ſome concurring circumſtances and obſervations, I reckon this would fall to about *gr.* 28. correſponding to our *gr.* 32. as in the table No. I, V. We have an obſervation of Mr De la Hire himſelf, whereby we find that his *gr.* 28. correſponded with *dig.* 51. *lin.* 6. in Mr Amontons's Thermometer ‡.

5. Mr Amontons made a fine ſtep to ſettle an univerſal Thermometer, had it not been for ſome inconveniences of which we had occaſion to take notice formerly ‖. In his the freezing point was at *dig.* 51. *lin.* 6. where our *gr.* 32 is; and the heat of

* Mem. Acad. Sc. 1700, p. 8. 1701, p. 10. 1702, p. 5. 1703, p. 3. 1704, p. 2. 1705, p. 4. 1706, p. 3. 1707, p. 2. 1708, p. 61. 1709, p. 3. 1710, p. 141.

† Ibid. 1702, p. 5. 1704, p. 4 1705, p. 4. 1706, p. 3. 1707, p. 2. 1708, p. 62. 1709, p. 3. 1710, p. 141. 1711, p. 2.

‡ Mem. Acad. Sc. 1710, p. 142.

‖ Eſſ. I. § 10.

of boiling water at *dig.* 73. where Fahrenheit's is at *gr.* 212; whence they can eaſily be compared together, as in the table No. I, VI.

6. * The Marquis Poleni gives us the reſult of a vaſt number of excellent and well-made meteorological obſervations, in which the heat and cold are meaſured with a Thermometer conſtructed in Mr Amontons's way. But, as his numbers are conſiderably different, I thought it well worth while to give a ſcheme too of his Thermometer in the table at No. VII.

7. Mr de Reaumur was very ſenſible of the difficulties of Mr Amontons's conſtruction, and propoſed a new and more certain way, as he thought, of making Thermometers. He determined to begin his ſcale at freezing water, and at boiling water marking *gr.* 80, dividing the intermediate ſpace of the tube into ſo many equal parts. I have on another occaſion † given my reaſons for thinking he was in ſome miſtake with reſpect to both theſe two periods of heat. But, as many very curious and uſeful obſervations have been made with his Weather-glaſſes, it will be of ſingular uſe to find out the correſpondence of his ſcale with that of Fahrenheit. His boiling-water heat is really only the boiling heat of weakened ſpirit of wine, coinciding

* Phil. Tranſ. 421. p. 205.

† Eſſ. I. § 20. 21.

eiding nearly, as I guefs, with Fahrenheit's *gr.* 180, and as his *gr.* 10¼ is the conſtant heat of the cave of the Obſervatory *, or our *gr.* 53. thence I find his freezing point, inſtead of anſwering juſt to our *gr.* 32, to be ſomething above *gr.* 34, as in the table No. I, VIII †.

8. On

* Mem. Acad. Sc. 1730. p. 503.

† The French at preſent uſe a Thermometer, which goes by the name of Reaumur's Thermometer, very different from this which the Author deſcribes. It is filled with mercury, has o for the freezing point, and 80 for boiling water. So that o of the modern, or mercurial Reaumur's Thermometer, correſponds with o of the old Reaumur's Thermometer, and 32 gr. of Fahrenheit's; but 80 gr. of the mercurial Reaumur's correſponds with 212 gr. Fahrenheit's. One degree of Reaumur's mercurial Thermometer is equal to 2¼ degrees of Fahrenheit's; but to ſave the reader the trouble of computation the following table is ſubjoined, ſhewing the correſponding degrees of Fahrenheit's ſcale for every one of Reaumur's.

R.	F.	R.	F.	R.	F.
0	= 32.	9	= 52.25	18	= 72.5
1	= 34.25	10	= 54.5	19	= 74.75
2	= 36.5	11	= 56.75	20	= 77
3	= 38.75	12	= 59	21	= 79.25
4	= 41	13	= 61.25	22	= 81.5
5	= 43.25	14	= 63 5	23	= 83.75
6	= 45.5	15	= 65.75	24	= 86
7	= 47.75	16	= 68	25	= 88.25
8	= 50	17	= 70.25	26	= 90.5

8. On principles very like thoſe of Mr De Reaumur, Mr De l'Iſle conſtructed his mercurial Thermometer: but, inſtead of freezing cold, he began his ſcale at the heat of boiling water, and, inverting the common order, marked downwards the ſeveral degrees according to the condenſations of the contained quickſilver, and conſequently by numbers increaſing as the heat decreaſed. This, as I obſerved *, was not in all glaſſes ſo uniform as were to be wiſhed. But as in Mr de l'Iſle's own

R.	F.	R	F.	R	F.
27	= 92.75	45	= 133.25	63	= 173.75
28	= 95	46	= 135.5	64	= 176
29	= 97.25	47	= 137.75	65	= 178.25
30	= 99.5	48	= 140	66	= 180.5
31	= 101.75	49	= 142.25	67	= 182.75
32	= 104	50	= 144.5	68	= 185
33	= 106.25	51	= 146.75	69	= 187.25
34	= 108.5	52	= 149	70	= 189.5
35	= 110.75	53	= 151.25	71	= 191.75
36	= 113	54	= 153.5	72	= 194
37	= 115.25	55	= 155.75	73	= 196.25
38	= 117.5	56	= 158	74	= 198.5
39	= 119.75	57	= 160 25	75	= 200.75
40	= 122	58	= 162.5	76	= 203
41	= 124.25	59	= 164.75	77	= 205.25
42	= 126.5	60	= 167	78	= 207.5
43	= 128.75	61	= 169.25	79	= 209.75
44	= 131	62	= 171.5	80	= 212

* Eſſ. I. § 28.

own ſtandards the freezing point is near to his *gr.* 150, coinciding with our *gr.* 32, it is eaſy to compare obſervations by them with the degrees of heat marked in ours by the table at No. I, IX.

9. Mr Crucquius * in Holland has made many curious and accurate meteorological obſervations with an air Thermometer. In freezing water the whole volume was 1070, in boiling water 1510; ſo as to render it very eaſy to collate his Thermometer with Fahrenheit's by the table No. I, X.

10. The moſt common Thermometers in England are thoſe made (and commonly very careleſsly made) after the ſtandard one kept in the Royal Society: and many faſhioned on this plan, by order of the Society, have been ſent into foreign parts to eſtabliſh a correſpondence of obſervations concerning the weather in different countries: for which reaſon it is the more incumbent on us to find out the principles of its conſtruction, ſo as to enable us to compare it with other Thermometers. The ſcale begins, or *gr.* 0 is marked at the top, I know not well upon what grounds, and thence the numbers increaſe downwards as the heat decreaſes. † In it it is ſaid to be *extreme hot* about the top of the ſcale, *hot* at *gr.* 25, *temperate* at *gr.* 45, and *gr.* 65 is marked as the *point of freezing*. But, by trials

* Phil. Tranſ. N. 381. p. 4.

† Ibid. N. 429, p. 103. N. 433, p. 337, 339. N. 434, p. 470.

trials made with ſome Thermometers that had been adjuſted pretty exactly with the ſtandard one in the Society-houſe, I found that the ſpirit fell to about *gr.* 78 or 79 in thawing ſnow; near 14 degrees lower than what had hitherto been reckoned; and this increaſes the wonder ſtill more, how Dr Cyrilli * ſhould have found the freezing point at Naples ſo high as *gr.* 55, if his Thermometer was truly adjuſted to the ſtandard.

But, to compare this Thermometer with thoſe of other people, it is neceſſary to find out where they correſpond in ſome other period of heat. What is marked *hot* or *temperate*, *&c.* on it, is indeed very equivocal. But, to put an end to the uncertainty, I tried and found by experience, that *gr.* 34½ anſwered to *gr.* 64 in ours: from whence their agreement is eaſily determined for all the reſt of the ſcale as in the table, at No. I, XI.

11. Sir Iſaac Newton † ſaw very well how vague and uncertain all the Thermometers in common uſe were; and therefore he contrived a new one, which I am ſurpriſed has gained ſo little ground in the world, as it is ſo ſimple and ſo eaſily imitated. You but begin your ſcale at freezing, and the diſtance from that to the heat of boiling water you divide into 34 equal parts or degrees, which, as they are large, may be ſubdivided at pleaſure. How ſuch a Thermometer anſwers to Fahrenheit's is ſeen at No. I, and XII.

12. There

* Phil Tranſ. N. 424. p. 336. N. 434. p. 407.

† Ibid. No. 270. p. 824.

12. There is a Thermometer in pretty frequent uſe in England, wherein they conceive the middle temperature of the air as neither hot nor cold, which therefore they mark *gr.* 0, and number both above and below, denoting by this means, as they conceive, the degrees of heat and cold of the ambient medium. Thermometers graduated in this way they commonly have in ſtoves and green-houſes for adjuſting the reſpective degrees of heat the various tender exotic plants require for maintaining their life and vigour. I do not believe that theſe Thermometers are made upon any regular or fixed principles. They commonly indeed mark freezing at *gr.* 30 under *gr.* 0. But in Mr Fowler's regulator, who furniſhes moſt of the green-houſes with them, he, on my deſiring him to try it, found that in melting ſnow the ſpirit fell to about *gr.* 34 under 0, and I found by ſome compariſons I made, that his *gr.* 16 coincided *q. p.* with our *gr.* 64: ſo that the whole correſpondence of this with Fahrenheit's Thermometer is eaſily determined, as in No. I, XIII.

13. Dr Hales* thought fit to employ a new conſtruction of a Thermometer in making his curious experiments. He began his ſcale or loweſt degree at freezing, or our *gr.* 32, and carried it up to *gr.* 100, which he marked where the ſpirit ſtood when the ball was heated in hot water on which wax ſwimming firſt begins to coagulate. In ſuch

* Veg. Stat. p. 37.

ſuch water I found Fahrenheit's Thermometer point at *gr.* 142; by which the two Thermometers might eaſily be compared. But by experience his *gr.* 100 falls conſiderably above our *gr.* 142. The reſult, from collating the two Thermometers together, is at No. I, and XIV. At a ſpring-head the Doctor found his to point at *gr.* 13. while ours ſtood at *gr.* 48 *.

14. At

* There is a mercurial Thermometer that is graduated in the ſame manner as this of Hales, namely having 0 for the freezing point, and 100 *gr* for the boiling water point. This Thermometer is uſed by the Swediſh chemiſts and philoſphers. One degree of this ſcale is equal to $1\frac{8}{10}$ of Fahrenheit's. Hence the following table of compariſon.

S.	F.	S	F.	S	F.
0	32	15	59	30	86
1	33.8	16	60.8	31	87.8
2	35.6	17	62.6	32	89.6
3	37.4	18	64.4	33	91.4
4	39.2	19	66.2	34	93.2
5	41	20	68	35	95
6	42.8	21	69.8	36	96.8
7	44.6	22	71.6	37	98.6
8	46.4	23	73.4	38	100.4
9	48.2	24	75.2	39	102.2
10	50	25	77	40	104
11	51 8	26	78.8	41	105 8
12	53.6	27	80 6	42	107.6
13	55.4	28	82.4	43	109.4
14	57.2	29	84.2	44	111.2

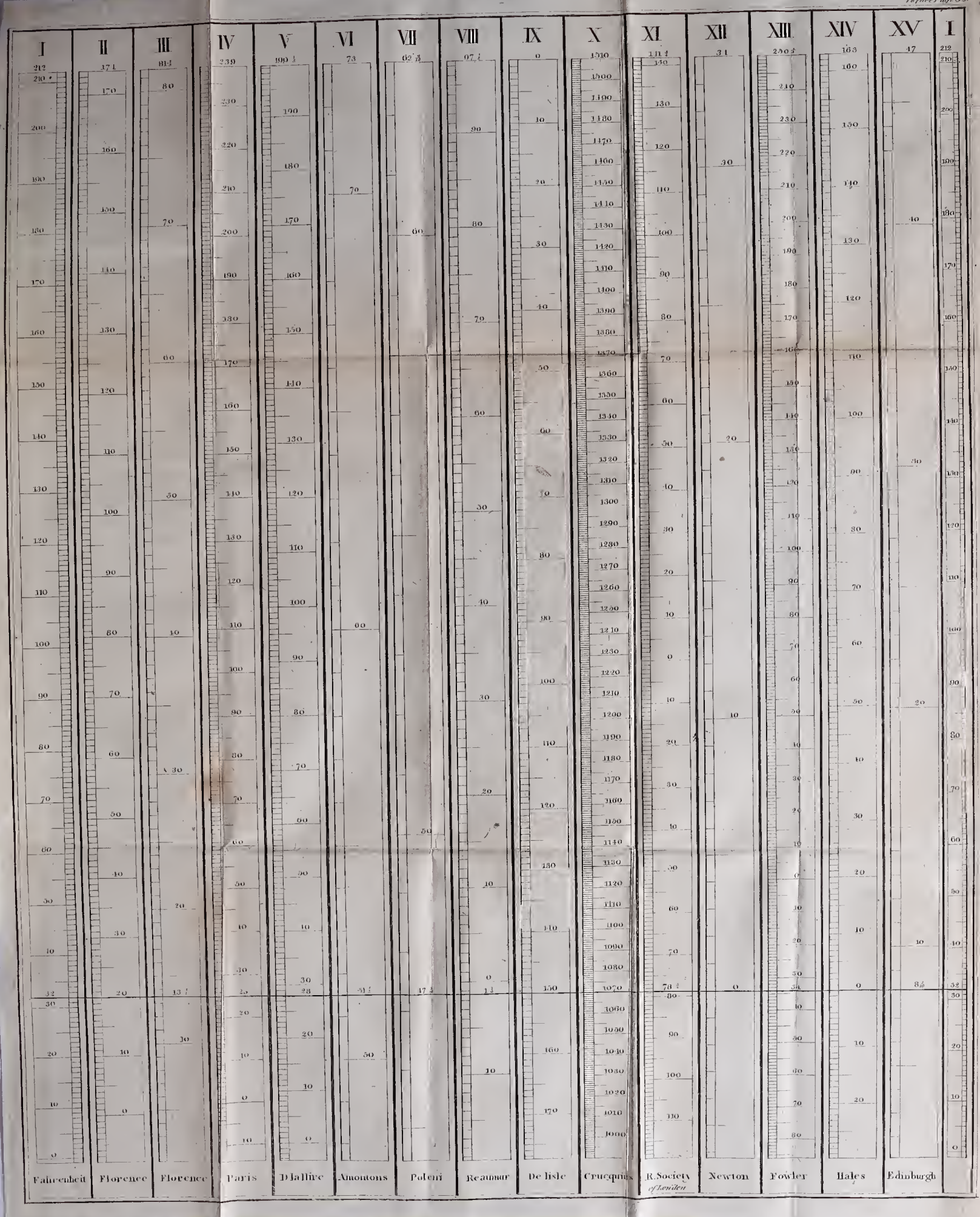
14. At Edinburgh they have for theſe many years kept a very exact regiſter of the weather, part of which is already publiſhed in their Medical Eſſays: for which it is well worth while to find out its relation to other Thermometers; which, from what the authors tell us, is eaſily done: for, * when the bulb was immerged in melting ſnow, the ſpirit ſtood 8.2 inches high, the heat of the human ſkin raiſing it to 22.2 inches; ſo that the intermediate 14 was divided into inches and tenths of

S.	F.	S.	F.	S.	F.
45	113	64	147.2	83	181.4
46	114.8	65	149	84	183.2
47	116.6	66	150.8	85	185
48	118.4	67	152 6	86	186.8
49	120.2	68	154.4	87	188.6
50	122	69	156.2	88	190.4
51	123.8	70	158	89	192.2
52	125 6	71	159.8	90	194
53	127.4	72	161.6	91	195.8
54	129.2	73	163 4	92	197.6
55	131	74	165.2	93	199.4
56	132.8	75	167	94	201.2
57	134.6	76	168.8	95	203
58	136 4	77	170 6	96	204.8
59	138.2	78	172.4	97	2 6.6
60	140	79	174.2	98	208.4
61	141.8	80	176	99	210.2
62	143 6	81	177.8	100	212.
63	145.4	82	179.6		

† Edinb. Med. Eſſ. I. p. 8.

of inches. And the heat of that perſon who graduated it I found to be *gr.* 97 in mine; from whence the compariſon at any intermediate degree of heat is very eaſy, as in No. I, XV.

15. We have heard of many other Thermometers, and of obſervations and regiſters of weather kept by them. But they have been generally ſo ill limited and deſcribed, that they are of no manner of uſe, and, to whatever purpoſe they might ſerve their authors, are to us as if they never had been.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